Alternatives for River Corridor Management

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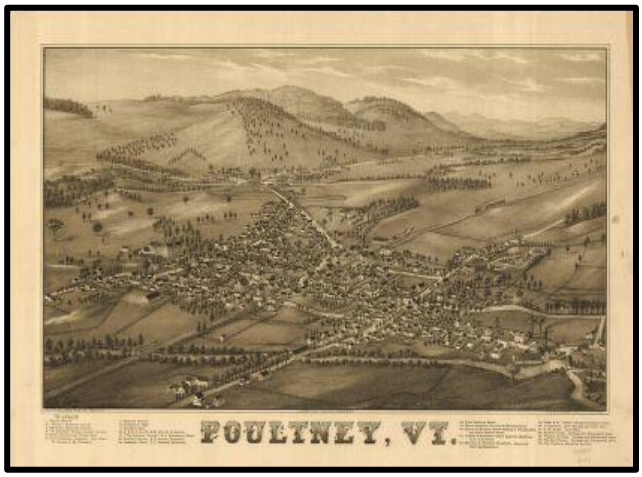
Vermont has found itself in an unending and escalating cycle of spending millions of dollars to maintain river channels, repair and rebuild flood damaged roads and bridges, and protect adjacent land uses from destruction by erosion or flooding, only to see these river management investments fail during the next flood or result in increased damage elsewhere. Riparian landowners are increasingly strident about real and perceived failures of state river management policies to address their concerns as they lose valued property with every significant runoff event. At the same time, stream channel erosion is increasingly cited as one of the most significant statewide water resource concerns, as evidenced by physical and biological indicators of aquatic ecosystem health.

River Management: The Stage is Set

Climate change, geologic events, major storms; all of these affect the flow of water, sediment, and debris and change the shape of river channels. Natural adjustments in river channel and floodplain geometry occur continually until dynamic equilibrium[1] is reestablished. These adjustments, however, have been overshadowed or largely magnified during the past two centuries in Vermont by those resulting from human-imposed changes to the depth and slope of rivers related to intensive watershed and riparian land uses. Nearly every Vermont watershed has streams "in adjustment" from the following sequence of events:



Deforestation – led to dramatic increases in the volume of water and sediment runoff. Channels and floodplains were buried in 1-3 feet of sediment, much of it glacial lake sediments that had yet eroded from higher on the valley perimeter. The channels rose up, then eroded back down through these materials, but terraces inaccessible to the rivers remain as a legacy to statewide deforestation;

Snagging & ditching – clearing boulders, beavers, and woody debris for logging (sluicing logs from uplands to village mill sites) and flood control, and ditching poorly drained land for agricultural improvements increased the rate of water and sediment runoff. Many pristine-looking mountain streams in Vermont contain only a fraction of their former channel roughness and resistance, and store far less sediment and debris.

Villages, farms, roads, and railroads – early settlements led to the first attempts to channelized rivers and streams which resulted in increases in channel slope, stream bed degradation (incision), and floodplain encroachments. Drainage Societies were started over 100 years ago to straighten and channelize streams to accommodate farms and early settlements. These channel works have been periodically maintained through gravel removal, realignment, channel armoring, and extensive flood remediation projects;

Mills, dams, and diversions – led to alterations in the amount and rate of water and sediment runoff. While dozens of dams are in place in each Vermont watershed today, historically there were hundreds. The small mill ponds of yesteryear have been replaced by larger dams used for hydroelectric generation and creating impoundments for flood control;

Gravel removal – advocated as a way to maintain straighter, deeper channels and control flooding; large-scale gravel mining resulted in bed degradation, head cutting, channel over-widening, and severe bank erosion. The interstate highways, state roads, and thousands of miles of dirt roads in Vermont were built on materials commercially extracted from the State's rivers;

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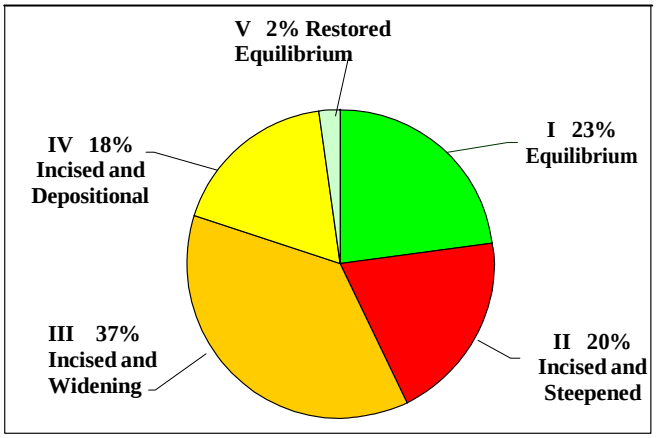
[1] **Dynamic Equilibrium:** The condition in which a persistent stream and floodplain morphology is created by the dynamic fluvial processes associated with the inputs of water, sediment, and woody debris from the watershed. The stream and floodplain morphology is derived within a consistent climate; and influenced by topographic and geologic boundary conditions. When achieved at a watershed scale, equilibrium conditions are associated with minimal erosion and channel adjustment, watershed storage of organic material and nutrients, and aquatic and riparian habitat diversity.

Encroachments, stormwater, and urbanization – have resulted in increased impervious surfaces and ditching to support economic development. Land use conversions have increased the rate and volume of water relative to sediment runoff, thereby contributing to channel incision and enlargement. Investments on lands previously occupied by river meanders or inundated during floods has created unrealistic and unsustainable human expectations in the absence of continuous or periodic channel management activities.

The cumulative effect of these human-related stressors has been varying degrees of vertical channel adjustment. Many channels have incised, eroding downward, losing access to floodplains which are essential to maintaining natural channel stability over time. Most Vermont rivers do not have access to floodplains during frequent run-off events (1-10 year floods) and in some cases even rare events, involving very large discharges (50-100 year floods), and resulting in a tremendous increase in channel adjustment and erosion. Channel incision is the "quintessential feature of dis-equilibriated fluvial systems" (Simon and Rinaldi, 2006[2]). Stream geomorphic assessments in Vermont have shown that 75% of assessed streams (950 miles) are unstable due to loss of floodplain access. Stream equilibrium has become the exception in Vermont, and the ecological benefits derived from naturally stable streams have repeatedly been deferred. Keeping rivers channelized and their floodplains from reforming have increased erosion of accumulated sediments, a legacy of hill slope deforestation, and accelerated the export of soils and nutrient from the upper and mid-watershed areas.



VT DEC Stream Geomorphic Assessment Results (2002-2007) explain the *State of Vermont Rivers.* Channel Evolution Stages II through IV represent departures from equilibrium where floodplain access and attenuation functions are reduced.

Vermont streams and rivers are evolving from these events and the loss of floodplain function. While some channelization continues today, many straightened, incised reaches are now widening and aggrading (building up with sediment transported from upstream). Recent major storm events have energized these channelized stream systems with inputs of water and sediment and, in so doing, have accelerated the physical adjustment processes (widening and aggrada- tion), as new floodplains develop along the rivers. The physical adjustment processes, most commonly observed as stream bank erosion, lead to the plan form or meander changes that are imperative for the river system to attain a natu- ral balance within its watershed. These adjustments cause property damage that, in many cases, have become increas- ingly intolerable for current landowners.

The Conflict: Today's Accounting

Traditional floodplain and channel management practices implemented to reduce the conflict between river corridor land uses and riverine flooding and erosion have largely worsened the problem out of a lack of respect for or understanding of the physical imperatives of river systems. Each time a river has been straightened, dredged, bermed, and armored to mitigate flood damage without respect for the physical form and function of its channel and floodplain, adjustments were set in motion that, more often than not, led to further erosion. The decades that often intervene between major floods have given people the misperception that their channelization projects actually worked. Generations have passed and people have forgotten that the rivers have been altered multiple times to "protect" human investments.

As our population and economy grow and our climate changes, the conflict between what is a physical imperative of the river system and our land use expectations becomes more and more intractable. The expenditure of millions of dollars will be necessary to restore or manage rivers and property after future floods. The high cost of restoration or management may be mitigated over time at a watershed scale where an understanding of the physical processes of rivers, i.e., fluvial geomorphic science, is used to restore both channel and floodplain function and protect riparian corri-

[2] Simon, A. and M. Rinaldi. 2006. Disturbance, stream incision, and channel evolution: The roles of excess transport capacity and boundary materials in controlling channel response. Geomorphology 79: 361-383.

dors from future ill-advised developments. Where there is neither the will nor the means to compensate people for their current investments, the cost of post-flood remediation and property protection will remain high in perpetuity.

On another part of the ledger, the cumulative impact of human actions have degraded physical habitat necessary to support healthy populations of some fish species and other aquatic life. Repeated channelization reduces the river bed and riparian structures upon which aquatic biota rely for shelter, food, and reproduction. Channelization is a pervasive threat to freshwater ecosystems, with dramatic effects on species abundance and diversity.

Unfortunately the growing conflict with river dynamics can not be treated as a one-dimensional economic problem to be solved for short term gain. The social, economic, and ecological return for implementing river corridor management practices that work toward equilibrium at the watershed scale will be largely enjoyed by generations to come. The long term challenge is to have more predictable investments with less erosion and healthier aquatic ecosystems, while minimizing short term economic losses along the way.

Short vs. Long Term Solutions: A Choice of Management Alternatives

For a straightened river in Vermont's geologic setting, it is only a matter of time before a flood drops a very large load of sediment at some point along its course. The wedge of sediment that builds in the channel during the recession of the flood may cause the river to avulse, or leave the channel, and head cut back through the landscape from the point where it returns to the channel further downstream. These events can erode river banks tens of feet and sometimes create whole new channels through adjacent lands, often someone's farm field.

A common, understandable response from landowners is to get the gravel out, return the river to where it was, and repair the eroded river bank with rock. Human nature will seek out or repeat solutions that protect the status quo, even if those same solution just failed. It would be wrong though, to pursue a short term approach that is doomed to failure and/or did not resolve the conflict at the expense of long-term solutions. The goal of the Vermont River Management Program is to deal with erosion and flooding conflicts in a manner that is consistent with the natural form and function of the river, and influences the physical adjustment processes in a way that reduces the long term conflicts, rather than just pushing the problem into the future to be dealt with by our children and grandchildren.

River management success, in the long term, will primarily be measured by our ability to solve problems at the watershed and river corridor scale; and secondarily, by how we resolve conflicts at individual erosion sites. From a fluvial geomorphic standpoint, this means recognizing that rivers transport and deposit sediment; and that natural stability and balance in the river system will depend on the river's opportunity to build and access a floodplain and create depositional features such as point bars, steps, and riffles to evenly distribute its energy and sediment load along the cross-section and profile of the river.

Managing the conflict between people's land use expectations and river dynamics should be based on an examination of alternatives and cost-benefit analyses, in both the short and long-term, to both private and public interests. To avoid the growing conflict between the changing course of rivers and our land use expectations, Vermont River Management and in collaboration with its partners is: 1) acknowledging the on-going river adjustments and the circumstances leading to their existence today; 2) striving to understand and be able to articulate the implications and consequences of different conflict management options; and 3) developing the ability to effectively address conflicts with river systems through the application of one or a combination of the following river management alternatives.

- **Passive Restoration**: Allow rivers to return to a state of dynamic equilibrium through a passive approach that involves the removal of constraints from a river corridor and the discontinuance of channel management activities. These actions allow the river, utilizing its own energy and watershed inputs to re-establish its meanders, floodplains, and self maintaining, sustainable equilibrium condition over an extended time period. Active riparian buffer revegetation and long-term protection of a belt width-based river corridor are essential to this alternative.

- **Active Restoration**: Restore or manage rivers to a geomorphic state of dynamic equilibrium through an active approach that may include human-constructed meanders and floodplains. Typically, the active approach involves the design and construction of a management application or river channel restoration such that dynamic equilibrium is achieved in a relatively short period of time. Active riparian buffer and bank revegetation and long-term protection of a belt width-based river corridor are essential to this alternative.

- **Channelization**: Maintain rivers in a channelized state through dredging and bank armoring applications. Mitigating the upstream and downstream effects associated with the alteration of sediment storage and transport processes may be an essential component of this alternative. Active revegetation and long-term protection of a wooded riparian buffer should be components of this alternative.
- **Combinations of the Above Alternatives**: In balancing social values and ecological functions, and accommodating the varying constraints that typically occur along a reach, project designs will combine elements of the other three alternatives based on the nature of the conflicts and the time and resources available for project implementation. A typical project in Vermont may involve active floodplain restoration, berm removal, passive channel restoration, corridor protection and limited bank armoring to protect a farm or road-related structure.

Informing the Alternatives Selection Process

The decision to armor an eroding bank or dredge a river to protect investments in the land becomes easy if you focus only on the short term costs and benefits. While one armoring or gravel removal project to stop erosion may be relatively benign, the problem arises from the cumulative effects of dredging and armoring up and down a river valley. At some threshold, bank armoring, post flood channelization, and changes in stormwater runoff combine to move a river out of equilibrium. Watershed-level instability places the viability of individual, seemingly benign, bank protection projects in jeopardy where significant channel adjustments are now underway.

The Vermont River Management Program (RMP) is working with its partners to focus on the long term benefits of a geomorphic management approach to both property owners and riparian ecosystems. The largest challenge will not be in applying the science to understand the river's slope and planform requirements, but rather how to redefine the relationship of public and private investments with fluvial dynamics in an equitable manner over time within a valley. The larger short term costs associated with using a geomorphic-based approach, where land conversion is necessary, become more acceptable and economically justifiable where channelization projects have failed repeatedly or in post flood remediation where major erosion, property damage, and channel avulsions have occurred. A passive restoration approach is often the most desirable alternative due to its lower upfront costs and maintenance, but is highly dependent upon landowners willing to accept what may be significant changes in land use expectations. It is extremely important that State and Federal agencies involved with river resource management work together to provide economic incentives and technical assistance to towns and landowners to make decisions that resolve immediate conflicts with the long term watershed solutions in mind.

Watershed and river corridor planning and the year-to-year implementation of management / protection / restoration projects will require information about the geomorphic condition of the watershed. Using the Vermont *ANR Stream Geomorphic Assessment Protocols*, the River Management Program and its partners are assessing stream condition, sensitivity, and adjustment processes. These data are proving to be ideal for problem solving in a watershed context, because they show the proximity of river reaches undergoing channel adjustment, and explain how stressors in the upper watershed may be affecting the geomorphic conditions downstream. The physical stream condition is largely a function of the type and magnitude of channel adjustments that are happening in response to changes in runoff patterns, sediment load, and the channel and floodplain modifications that have occurred in a watershed.

The Vermont River Management Program is promoting an analysis of reference fluvial processes and geomorphic condition. The RMP is examining the watershed and reach-scale stressors which explain the departure (from reference) and sensitivity of existing conditions. Mapping the departure and sensitivity of reaches in the context of vertical and lateral channel constraints throughout the stream network can explain the type and rate of channel evolution processes underway, and how adopting certain management practices can accommodate, preserve, or restore equilibrium conditions over time. The VT RMP has drafted a *"River Corridor Planning Guide"* to help its partners evaluate physical stressors, channel response, and river management alternatives.

Ideally, river corridor plans involving all stakeholders would articulate how public and private land use and infrastructure investments would be balanced with the goal of achieving river equilibrium conditions. Vermont is working toward an incentives-based, multi-agency river management program that seeks incremental progress with each landowner toward protecting, managing, and restoring the river corridors. Real progress will be measured over decades.